SCAN Testbed, Overview and Opportunity for Experiments

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SCAN Testbed
Research & Technology Goals & Objectives

- **INVESTIGATE the APPLICATION of SDRS TO NASA MISSIONS**
  - Mission advantages and development/verification/operations aspects
  - On-Orbit Reconfiguration
  - More process intensive functions within the radio subsystem

- **SDR TECHNOLOGY DEVELOPMENT**
  - SDR Platforms to TRL-7
  - SDR platform hardware & waveform compliant to STRS, Foster Agency adoption
  - Understand/characterize space effects and SDR performance

- **VALIDATE FUTURE MISSION OPERATIONAL CAPABILITIES**
  - Capability representative of future missions
    - Comm data rate, performance, navigation/ GPS, networking/routing
  - Understand SDR performance (reliability, SEE, telemetry, instrumentation)
  - Multiple and simultaneous RF Links (Ka-band, S-band, L-band/GPS)
  - Experimenter sw applications (On-board networking , DTN, routing, and security applications)

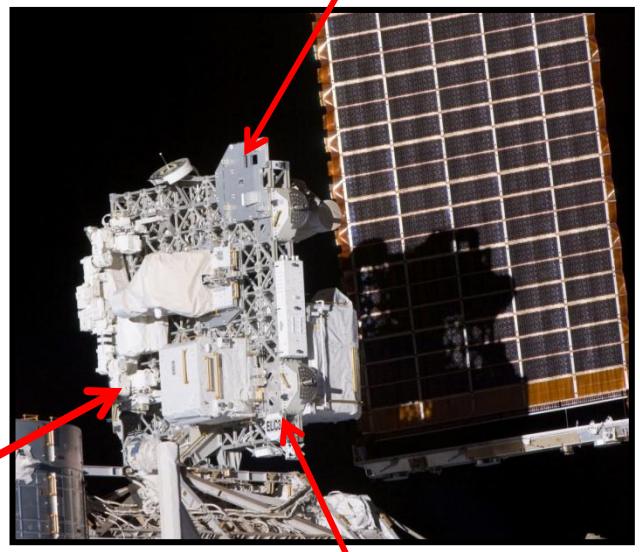
SCAN Testbed Overview

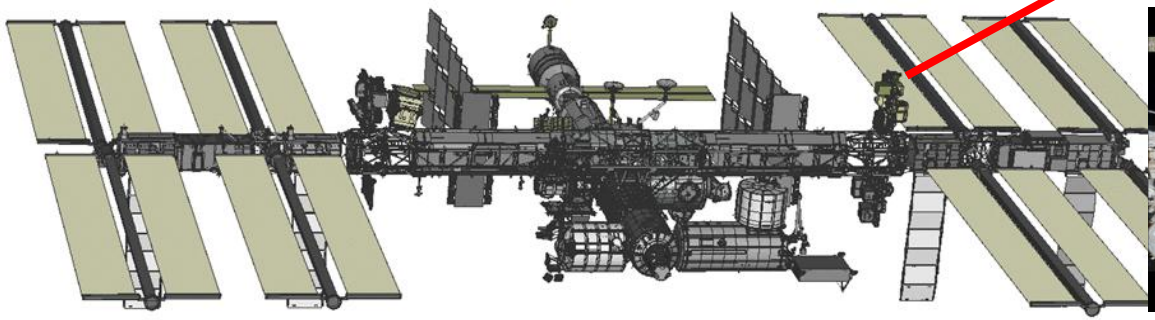
- **Sponsored by the NASA Space Communications and Navigation (SCaN) Program.**
  - Across multiple Center; GRC, JPL, GSFC, JSC

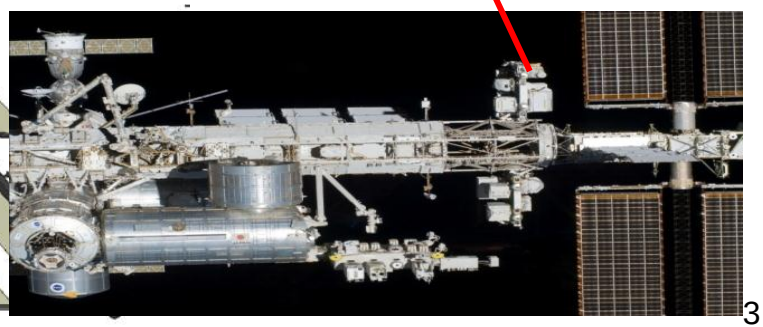
- **Launch to the International Space Station (ISS) on JAXA H-II Transfer Vehicle (HTV-3) summer 2012**
  - Utilizes a Flight Releasable Attachment Mechanism (FRAM)-based payload interface and is installed on the Expedite the Processing of Experiments to Space Station (ExPRESS) Logistics Carrier (ELC) at the ISS P3 location.

- **The Flight System is a Class D payload planned to operate for five years on ISS (min design life is two years).**
  - Ground System includes a flight-Like system for new radio software development

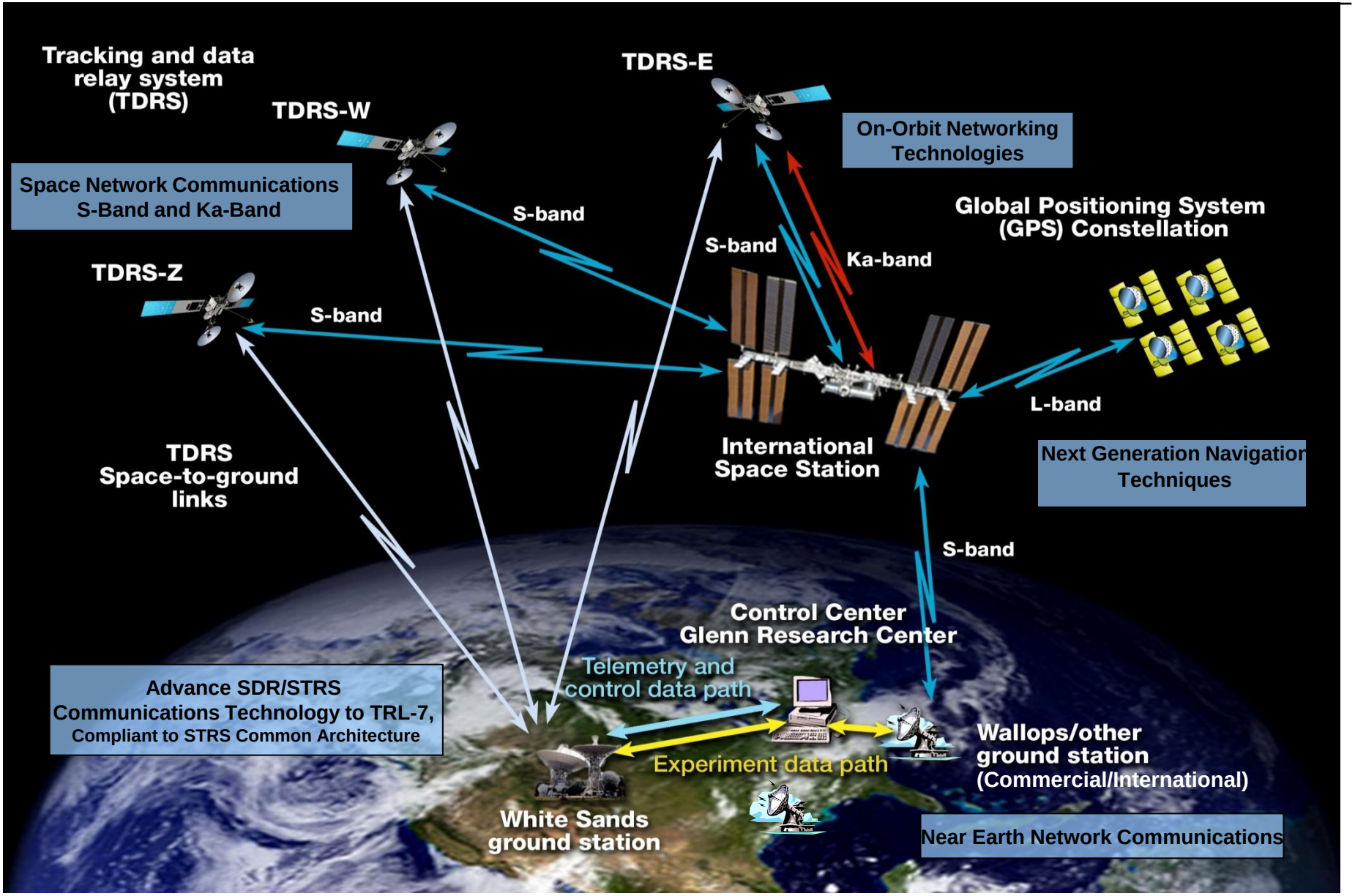
Future Home of SCAN Testbed





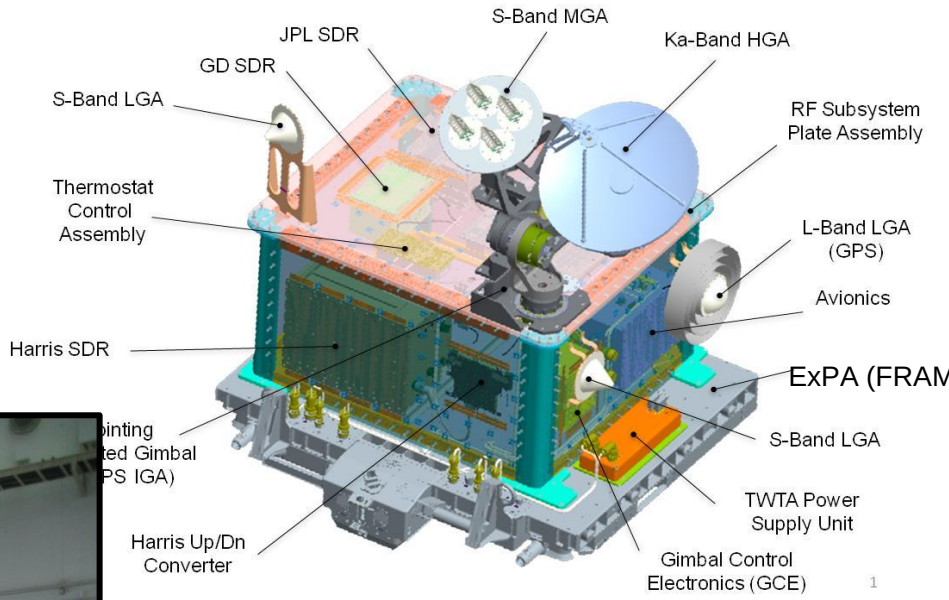


Concept of Operations & Connectivity



SCAN Testbed - Flight System Overview

Flight System Subsystems
Mechanical/Thermal
Avionics/Electrical
SDRs
RF/Antennas
APS
EXPRESS Pallet Adapter (ExPA)-
Flight Releasable Attachment Mechanism (FRAM)



JAXA Experiment

SCAN Testbed Experiment

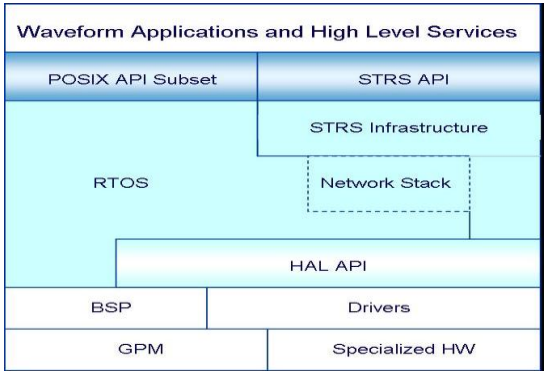
Installed on an EP-MP for HTV Integration

Flight System Mass w/out ExPA, lb	486
ExPA Mass, lb	260
Total Mass, lb	746

SDRs are the core "instrument" of the SCaN Testbed Communication System

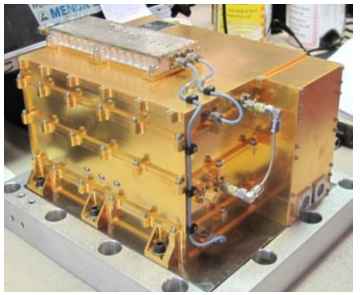
STRS SDRs

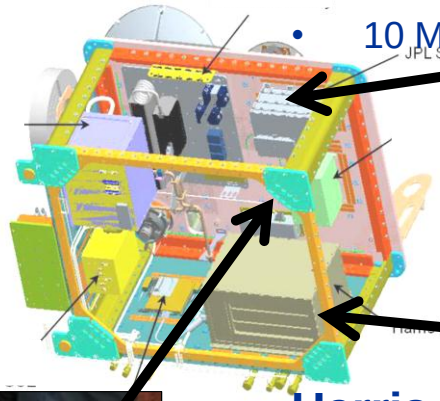
- Software Abstraction
- Single Standard on SDR and WF



JPL/L-3 CE

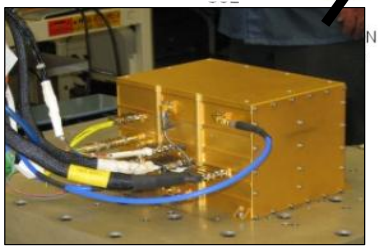
- S-band SDR
- 6 MHz wide channel
- L-band receive (GPS)
- Virtex II, Sparc Processor (100 MIPS), RTEMs
- 10 Mbps Class





General Dynamics

- S-band SDR
- 6 MHz wide channel
- Virtex II,
  ColdFire Processor (60 MIPS), VxWorks, CRAM (Chalcogenide RAM) Memory
- 10 Mbps Class

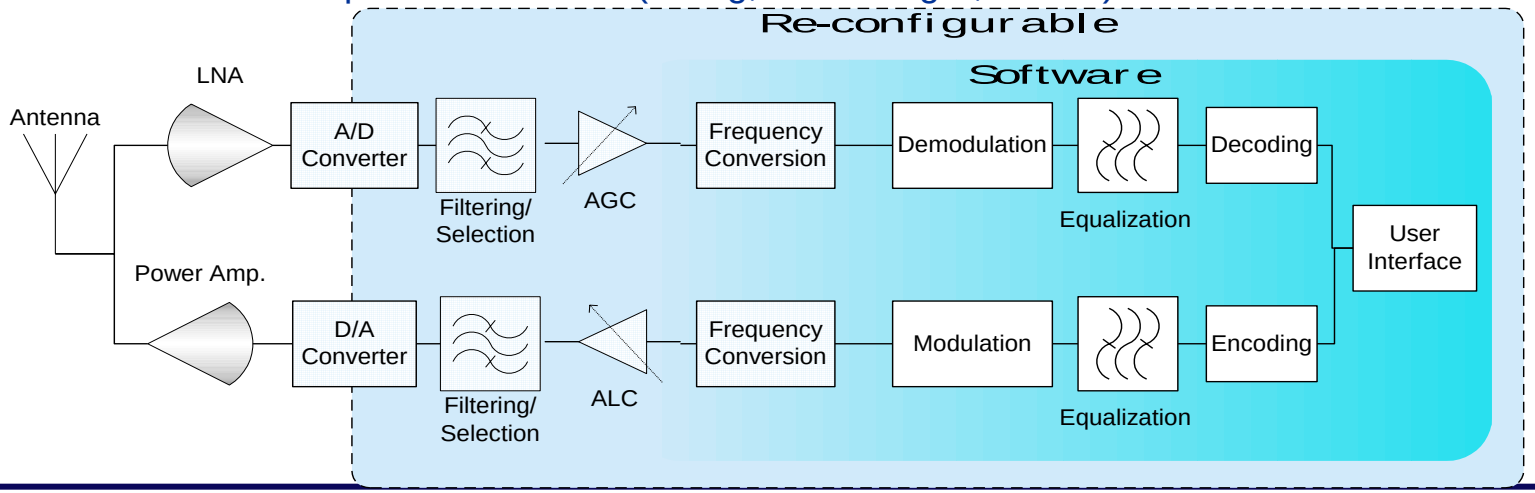


Harris

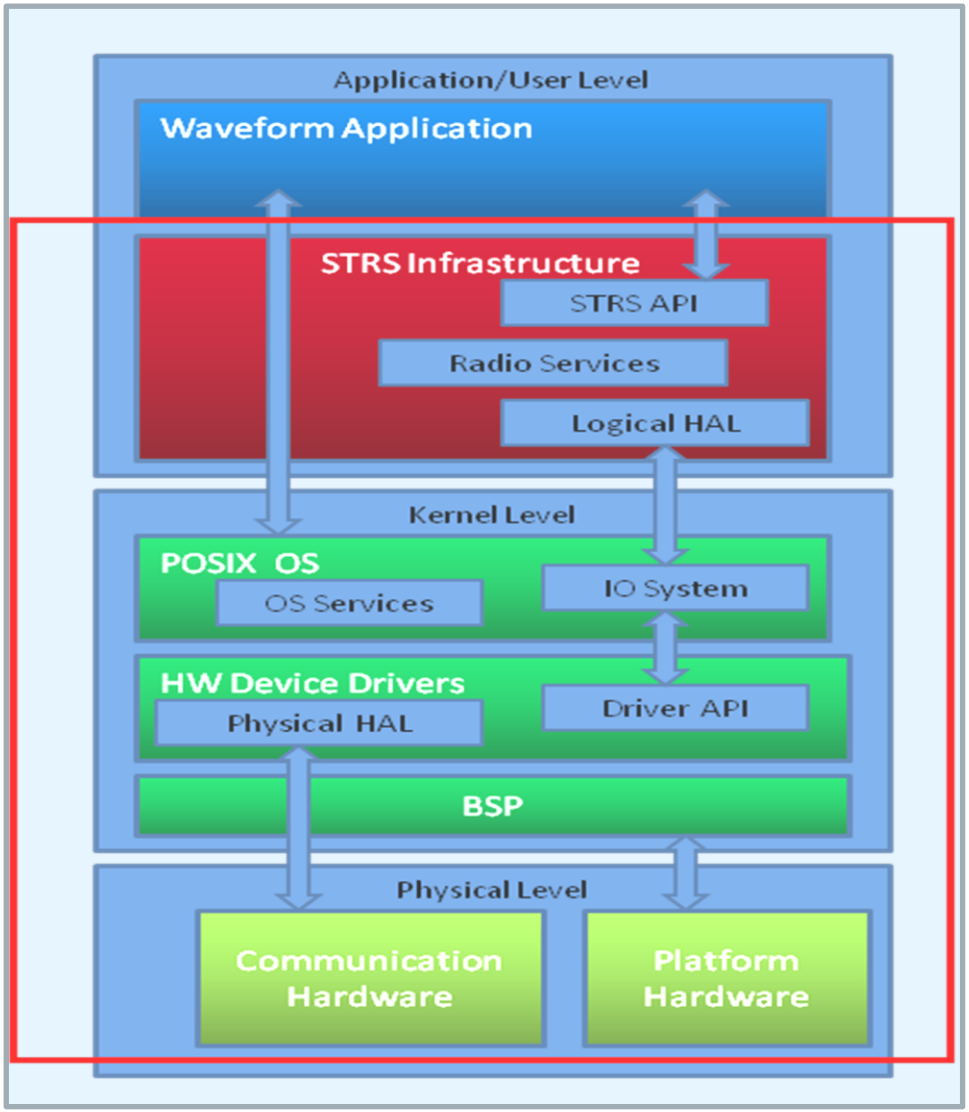
- Ka-band SDR
- 225 MHz wide channel
- Virtex IV,
  AiTech-PowePC Processor (~700 MIPS), DSP (1 GFLOP), VxWorks, Scrubbing ASIC
- First Ka-band transceiver
- >100 Mbps Class

Software Defined Radio "SDR 101"

- Hardware and software that converts user data to over-the-air signals
- Hardware – Signal processing, RF, power, thermal
  - Shift from fixed hardware to flexible, reprogrammable hardware (FPGA, processor)
  - Traditional hardware remains at RF front end (ADC, DAC, filters, amplifiers)
- Software – Application (aka waveform), Managing (STRS)
  - Application Software – communication, navigation, networking functions
    - e.g. modulation, coding, filtering, data framing, routing, orbit determination
  - Managing Software – Controls the application software on the radio platform.
    - Loads/unloads application code and data to/from memory
    - Responsible for interprocess communications between software components
    - Provide platform services (timing, file manager, events)



STRS Simplified View



- Abstract app sw from underlying HW
  - Reduce mission dependence on radio provider for reconfigurations years after development/launch.
  - Minimum set of hardware and software interface
- Promote portability/reuse
  - Avoid proprietary application designs/ implementations.
- Mission flexibility, for different levels of available resources. – scalable
- Architecture simplified by mission planning and hw resource allocation.
  - No radio hardware discovery or dynamic WF allocation change across hardware – fewer resources (e.g. power, memory)
- Enable waveform component contributions to repository for reuse

SCaN Testbed Experiment Waveforms

(Launch Capability)

			Transmit (Return) Link		Receive (Forward) Link		
TDRSS Mode	Platform Provider	Waveform Provider	Modulation	User Data Rate (kbps)	De-modulation	User Data Rate (kbps)	Coding/ Decoding
S-band DG1, Mode 1	GD	GD	SQPN	24, 192	QPSK	18, 72	Rate 1/2 Viterbi
S-band DG1, Mode 2	GD	GD	SQPN	24, 192	QPSK	18, 72	Rate 1/2 Viterbi
S-band DG1, Mode 3	GD	GD	QPSK	<1000	QPSK	1000	Rate 1/2 Viterbi
S-band DG2	GD	GD	SQPSK	<1000	QPSK	1000	Rate 1/2 Viterbi
S-band DG1 Mode 2	JPL	GRC/GSFC	BPSK	24	BPSK	18	Rate 1/2 Viterbi
S-band DG2	JPL	GRC/GSFC	BPSK	192	BSPK	155	Rate 1/2 Viterbi
Ka-band DG2	Harris	Harris	SQPSK	100 Mbps 12.5 Mbps	BPSK	12.5 Mbps 3 Mbps	Rate 1/2 Viterbi

Specific waveform variations lead to numerous (>100) configurations

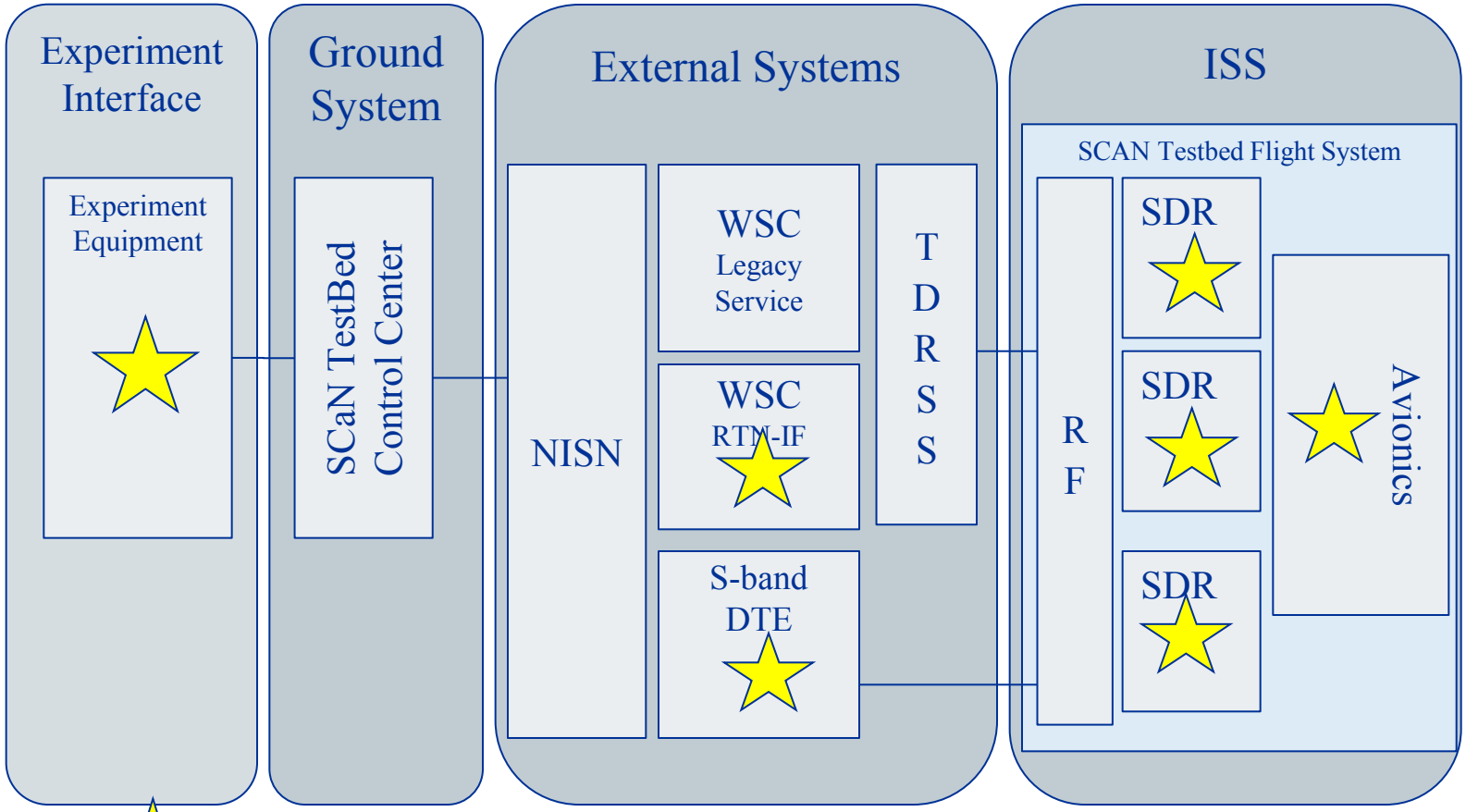
Flight Test and Measurements Provide Validation of New Technologies

- **SDR Platform Technology**
  - Reconfiguration (time, reliability, operations)
  - Application Integration
  - Space Effects (SEU, processing, memory, thermal, power)
- **System Architectures**
  - Connectivity: TDRSS and ground…relay and surface
  - Multi-band, multi-TDRSS links
  - Multiple access techniques (TDRSS)
- **Communication Applications**
  - Link capacity – data rate, bandwidth efficiency, coding schemes
  - Adaptive communications
  - Cognitive Radio/Applications
  - Data link protocol verifications
  - Link performance
    - Error performance/rate (BER), Eb/No (SNR)
    - Error distribution
  - Link characterizations

Flight Test and Measurements Provide Validation of New Technologies

- **Demo SDR-based GPS**
  - Comm and navigation functions time-multiplexed on common hardware
  - Improved position, velocity, time (PVT)
  - TASS enhancement of GPS navigation
  - Re-broadcast of GPS corrections to other s/c
  - Navigation data fusion
- **Evaluation of new GPS**
  - New signals (L5) to be added without rebuilding hardware
- **Precision relative navigation**
  - Rendezvous and docking
- **On-Board Routing**
  - Connectivity, network characterization, link statistics
- **Delay/Disruption Tolerant Networking (DTN)**
  - Automated store-n-forward
  - Adaptive routing
  - Traffic prioritization
  - Link layer error control/ cross link optimization
- **IP in Space**
- **Common Command/Data Interface Experiments**
- **Distributed Processing**
  - Efficiency, reliability

Experimenter Access Points within SCaN TestBed System



= Experiment Element (e.g. sw, fw, hw, component)

Experimenters have access to
Flt SDRs, avionics, Gnd SDR, various ground points

Call for Experiment Proposals

- After Commissioning is complete, the testbed will be available for experiments
- Experiment announcement call in mid 2012 for external experiments
  - The call will go to NASA, industry, academic partners and other government agencies
  - Experiments selected will complement experiments already selected from internal to NASA and through the SBIR process
- Goal is to develop an experiments program to utilize the SCaN Testbed for the benefit of the Space Communication and Navigation (SCaN) Program, and NASA

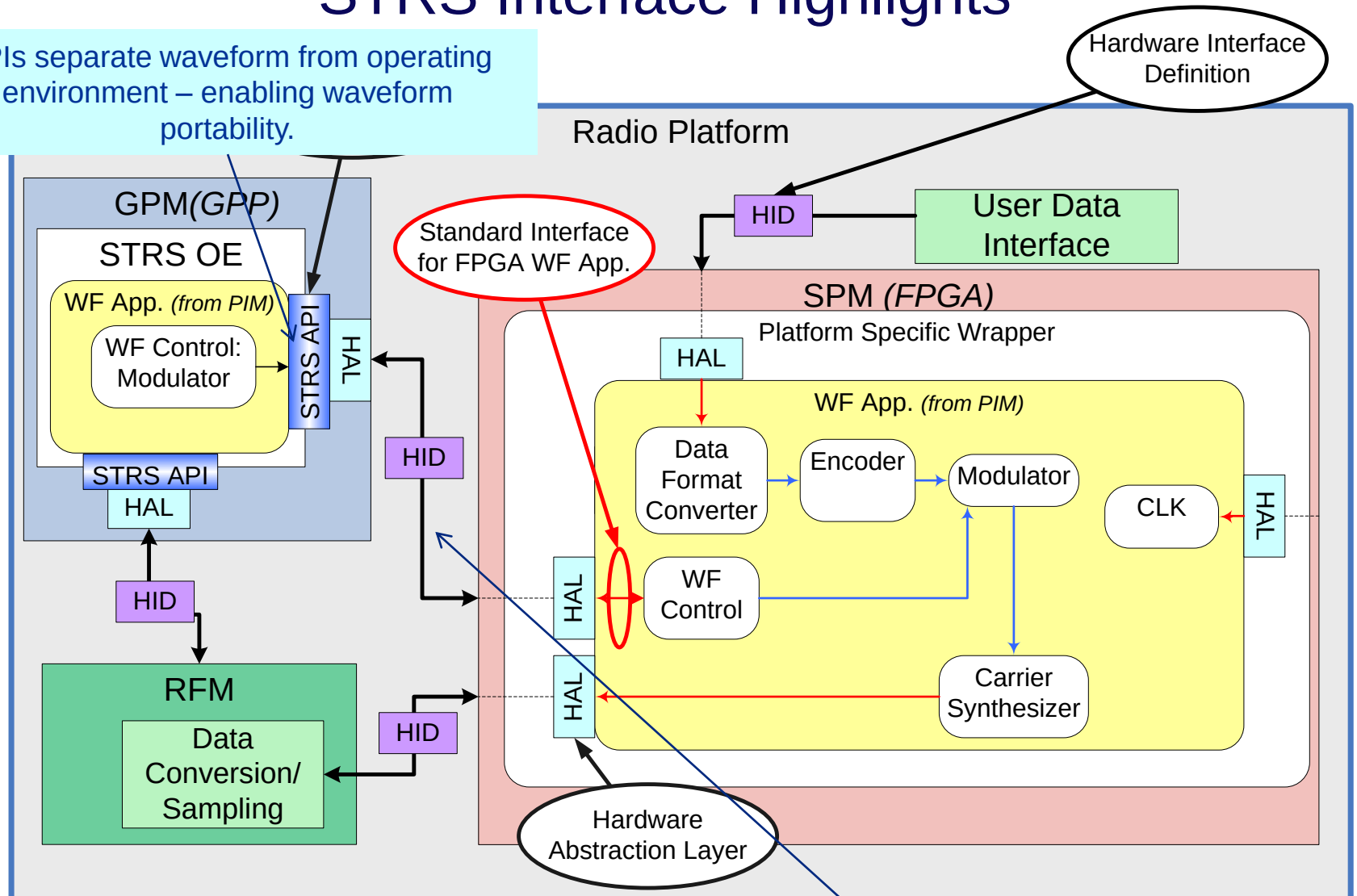
Summary – SDR Experiment on ISS

- SCaN Testbed scheduled for launch in mid-2012
- Experiments Program seeks participation by NASA, industry, academia, and OGA to use the SCAN Testbed.
  - Call for experiments released in mid 2012.
- Broad participation will create a forum to exchange ideas and results, create new experiments, new partnerships, and disseminate results
- STRS abstracts waveform from underlying hardware
  - Increase the base of domain experts around a common standard.
  - Seeking input to STRS by other agencies (standardization effort in FY12)
- SCAN Testbed reduces the risk of infusing SDRs and their applications (comm, nav, networking) into NASA missions

Backup

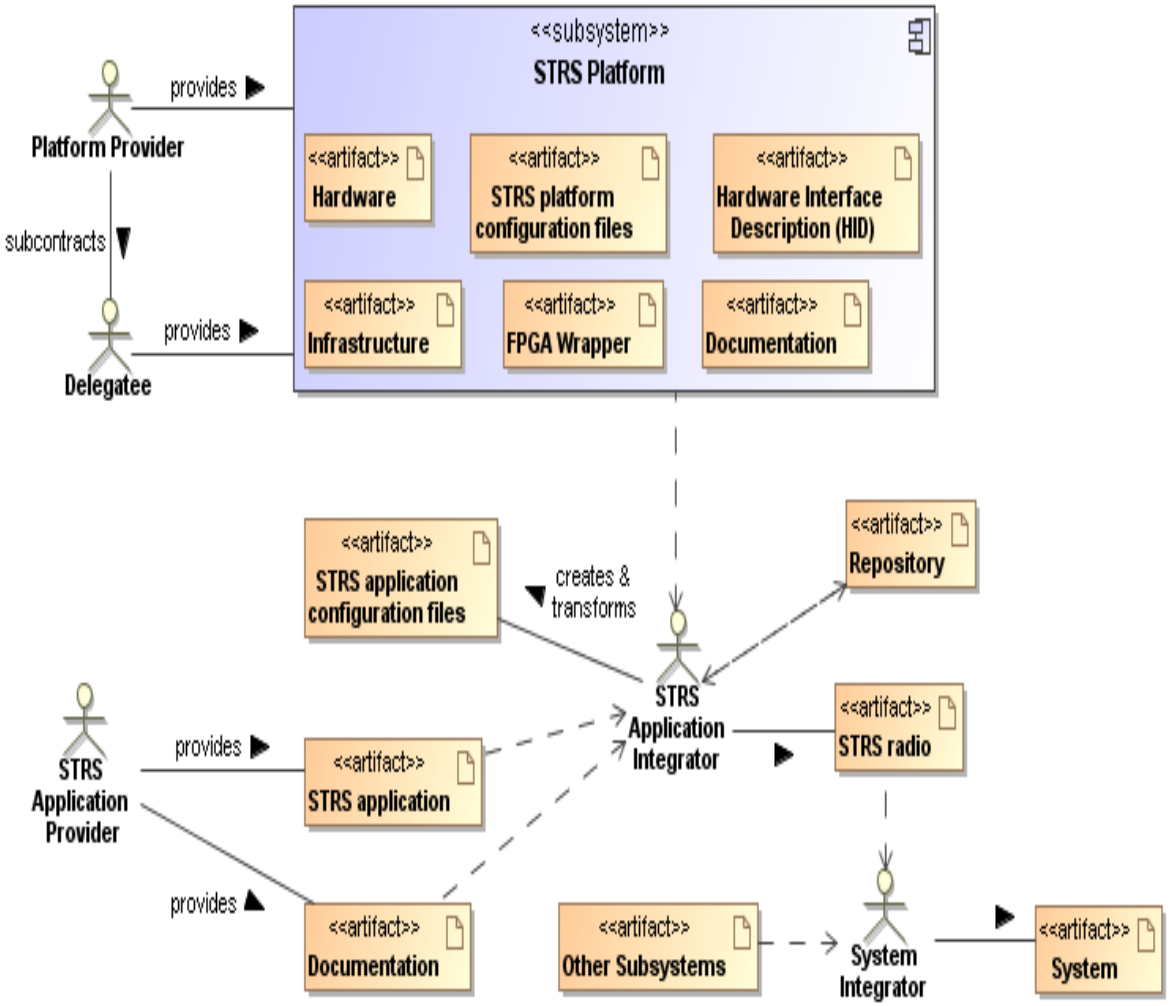
STRS Interface Highlights

APIs separate waveform from operating environment – enabling waveform portability.



HID identifies hardware resources available to waveform developer, separating WF from HW dependency

SDR Developer/Operations Roles



- Platform Supplier
  - Hardware
  - Operating Environment
- Waveform Developer
  - Waveform App
- SDR Integrator
  - Combines waveform applications with the platform.
  - non-SDR model, the integration is done at the radio manufacturer
- System Integrator
  - integrates the complete radio (hw/wf) with the rest of the spacecraft.

Acronym List (1 of 2)

- API – Application Programming Interface
- ASIC – Application Specific Integrated Circuit
- BER – Bit Error Rate
- BPSK – Bi-Phase Shift Keying
- BSP – Board Support Package
- CE – Cincinnati Electronics
- DSP – Digital Signal Processing
- DTE – Direct to Earth
- DTN – Disruptive Tolerant Networking
- EDAC – Error Detection and Correction
- ELC – EXPRESS Logistics Carrier
- FPGA – Field Programmable Gate Array
- FW - Firmware
- GD – General Dynamics
- GPM – General Processing Module
- GPS – Global Positioning System
- GRC – Glenn Research Center
- GSFC – Goddard Space Flight Center
- HAL – Hardware Abstraction Layer
- HID – Hardware Interface Definition
- HGA – High Gain Antenna
- HPA – High power Amplifier
- HW - Hardware
- JPL – Jet Propulsion Lab
- JSC – Johnson Space Center
- LGA – Low Gain Antenna

Acronym List (2 of 2)

- OE – Operating Environment
- OGA – Other Government
- QPSK – Quadrature Phase Shift Keying
- PVT – Position, Velocity, Time
- RF – Radio Frequency
- RTN - Return
- RTOS – Real Time Operating System
- SDR – Software Defined Radio
- SEE – Space Environment Effects
- SEU – Single Event Upset
- SN – Space Network
- SNR – Signal-to-Noise Ratio
- SQPN – Staggered QPSK PN Spread
- SQPSK – Staggered Quadrature Phase Shift Keying
- STRS – Space Telecommunications Radio System
- SW - Software
- TDRS – Tracking Data Relay Satellite
- TDRSS – Tracking Data Relay Satellite System
- TRL – Technology Readiness level
- TWTA – Traveling Wave Tube Amplifier
- V2 – Vitex II
- V4 – Virtex IV
- WSC – White Sands Complex
- WF - Waveform